

## Sustainable food crop production in karst area of Parigi, Pangandaran, West Java: preliminary study

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### Abstract

Karst formations in Selasari and Parakanmanggu Village of Parigi District, Pangandaran Regency, West Java includes dolines, subterranean stream, springs, and karst hills are useful for agriculture. The purpose of this study was to 1) identify the used of karst area for rice cultivation and local trees in karst area; 2) evaluate the benefit of rice cultivation and local tree for local communities and 3) asses the legal aspect for supporting food crop production. The study was done using qualitative-descriptive method with the primary data obtained from field observations, soil analysis, local tree identification, and interviews. Secondary data was obtained from the Regional Government and the National Geological Agency. The results showed that rice cultivation has been carried out in suitable soil by using simple and rainfed irrigation. Local fruit, herbs, timber and shade-ornamental tree grow naturally on the karst area. Tree logging without significant revegetation caused water supply shortage so that farmers only grow rice once a year. Although the rice productivity of both villages is lower than average rice productivity of Pangandaran Regency, rice is important to support local inhabitant's consumption and family income. Land Use Plan year 2018 regulates the general provisions on zoning regulations for agriculture in susceptible area but the regulation does not mention the karst areas. This study suggested that tree conservation is needed to maintain the existence of rice fields. Land use planning for agriculture in the region must be based on integrated considerations of rice cultivation and local tree conservation.

**Keywords:** *Karst region, Land conservation, Local tree, Rice.*

**JEL Classification:** Q15, Q23

### INTRODUCTION

Karst is a type of landscape in the form of a basin or small hill which is formed through erosion and dissolution of limestone and dolomite (Hartmann, Goldscheider, Wagener, Lange, & Weiler, 2014). Karst area is a medium for water infiltration into the ground and creating groundwater and springs. On the surface, carbonate stones go

through dissolution process by rainwater and thus forming karst landscape which is characterized by hill, doline, cave and river (Radulovic, 2013).

Karst surface erosion causes the main rocks (regolith) to be exposed by the atmosphere and later form the soil (Klimchouk, 2014). Regolith weathering is important initial stage of soil formation; and integral part of agriculture in the karst area. The process of soil formation is slow and susceptible to erosion mainly in sloping area where rainwater easily moves the soil to the lower part. Eroded soil from the sloping area settles in the karst foothills and karst valleys (doline) where agriculture taken place. Soil in karst areas is generally high in calcium and low in fertility (Yang, Liang, Chen & Cao, 2015) but suitable for local food production.

Parigi district in Pangandaran Regency of West Java has karst landscape include hill and doline that intensively used for agriculture by communities. In most part of Pangandaran, agriculture is still important economic activity. Agriculture in the broad sense contributed to at least 26% of Pangandaran revenue; especially from rice, coconut, livestock and fisheries (Pangandaran dalam Angka, 2017).

Agricultural area in Pangandaran Regency is approximately 15,125 ha which is written in article 47 paragraph (2) of Pangandaran Regency Regulation No. 3 year 2018 about Pangandaran Regency Spatial Plans of 2018 - 2038. Allocation of land for agriculture in Parigi District area were 2,095 ha of rice field and 8,687.57 ha of dry land. Rice field consists of simple-irrigated and rainfed field which cover the area of 1,421 ha and 714 ha respectively. Parigi has 906 ha of State forest, 981.21 ha of community forest and 4,493.63 ha of community estate (Parigi dalam Angka, 2018: 31) which plays an important role in protecting land and water for agriculture, mainly lowland rice field.

Rice cultivation in the karst area of Parigi is important for food security as well as community income. Water is an important part in agriculture; the existence of ground water, subterranean stream, surface water and springs as a source of water for agriculture in karst areas (Baker and Groves, 2008). The watercourse is depends on karst hydrological functions that can be optimized, among others, by maintaining the presence of vegetation on karst. The karst formation process will create unique microclimates and habitats (Efe, 2014) that support indigenous plants and tree. On the other hand, without appropriate protection, vegetation in karst is vulnerable to damage by excessive anthropogenic activities. Protection of tree in karst hills is needed to strengthen the role of karst on water supply for rice field in the downhill. Hence, land use planning in the region should be based on an integrated consideration of both systems (rice cultivation and local tree) rather than considering the two systems independently (Nautiyal, Maikhuri, Semwal, Rao, & Saxena, 1998).

The geological aspects of karst in the Parigi District have been identified by the National Geological Agency in 2017 and 2018, but the existence of agriculture and vegetation in karst ecosystems of Parigi has never been studied. The objective of this research was to 1) identify the used of karst area for rice cultivation and local trees in karst area; 2) evaluate the benefit of rice cultivation and local tree for the communities living in studied area and 3) asses the legal aspect for supporting food crop production.

## METHODS

The study was accomplished from July 2018 to September 2018 in Selasari Village and Parakanmanggu Village which located in Parigi District, Pangandaran Regency, West Java (Fig. 1). Both locations are located in the western part of Pangandaran where geological aspects of the karst have been reviewed by the National

Geological Agency in 2017. A humid tropical climate characterizes the area. The mean maximum and minimum monthly temperature at July and August 2018 was 28.7°C and 22.7°C respectively. In general, Pangandaran Regency has dry season (east season) and rainy season (west season) with annual temperature between 20°C-30°C, rainfall of 1.647 mm, and humidity between 85%-89%.

The research was carried out by used of descriptive qualitative method based on primary and secondary data. The description of karst land use was collected by field observations, interview and Focus Group Discussion (Astalin, 2013) that involve the communities living in study area. Rice production system was directly observed in field supported by primary and secondary data on soil characteristics. Soil organic carbon and acidity was measured from soil sample by using standard method for soil analysis (Eviati and Sulaeman, 2009); soil samples were taken by composite method.



**Figure 1.** Pangandaran Regency is located at the southern and eastern ends of West Java Province

Purposive sampling based on non-random and subjective consideration; and convenience sampling which select the samples according to our wishes were chosen to establish a sample of karst area, as well as rice field and tree area to be studied. Secondary data were obtained from the Development Planning Agency and the Agriculture Office of Pangandaran Regency; and the National Geological Agency in Bandung, West Java. Local perennial tree exploration was carried out by identifying local trees on karst hills and grouping them according to their use by residents. Local names of trees were obtained through interviews and scientific names were determined based on binomial nomenclature.

## RESULTS AND DISCUSSION

Parigi District has some geological features include dolines, subterranean stream, springs, and karst hills (Gunawan, Afrian, & Supratman, 2017) to support rice cultivation. Spring and subterranean watercourses way that come up to the surface (Fig 2) play an important role to irrigate rice field in the ridge of karst hill and doline.



**Figure 2.** Watercourses way in Karst area at Parakanmanggu Village (left) and Selasari Village (right) in Parigi District

### **Rice Cultivation in Doline of Karst Area**

Rice fields was main agriculture in doline (Fig 3); a closed basin where eroded soil accumulated (Radulovic, 2013) forming a thick solum on its surface. The soil thickness in rice fields are up to 50 cm; enabling the cultivation of lowland rice that only requires a maximum depth of plow layer of 40 cm (Wahab, Abdulrachman, Suprihanto, & Guswara, 2017).



**Figure 3.** Rice field and vegetable in the dike irrigated by watercourse way from karst hill around the field.

Most of lowland rice field in both villages received water from simple irrigation system made by the communities and rainfed irrigation. Before transplanting, soil is plowing by mixing with roots of previous paddy and then harrowing with traditional methods; farmers do not use tractor in soil preparation. Paddy farmers carry out conservation farming techniques by forming terraces in steep land; and they prefer to cultivate the rice in the flat area of doline instead of steep area. Rice is never grown on the ridge of karst hill due to shallow soil and rock will inhibit root growth.

Soil contained soil organic matter as much as 2.4% equal to 1,39 % of organic carbon so that the soil particles are stable, support the development of soil microbes, the availability of plant nutrients, and provide optimal growing media for roots (Bot and Benites, 2005). Neutral acidity of 6.8 ensure the availability of macronutrient nitrogen, phosphate and potassium; as well as prevents excessive uptake of ferrous ions and other (heavy) metal (Hartatik, Sulaeman & Kasno, 2005; Oseni Olalekan, Taiwo Abayomi,



Ijaola Taiwo, & Yenusa Luqman 2016). The method of rice cultivation in study area is in line with the principles of Integrated Crop Management for irrigated lowland rice through the adoption of technology which adjust with local conditions to preserve the nature (Abdulrachman, Mejaya, Sasmita, & Guswara, 2013).

Rice production in Pangandaran at 2016 was 189,990 tons in which 98,68% was lowland rice but no rice production data of 2017 as well as 2018 (Pangandaran dalam Angka, 2019). The harvested area of lowland rice Pangandaran Regency was 31,131 ha while in Parigi was 9,928 ha in 2016 (Pangandaran dalam Angka, 2019). Parigi Subdistrict didn't have accurate data of both Selasari and Parakanmanggu rice production. The area of paddy fields in both village is 359 ha. According to personal communication with Agricultural Extension Worker, the average productivity of lowland rice in both villages are only 4 tons/ha lower than that of Pangandaran, 6-8 t/ha. However, both villages contributed 1,436 tons of rice to Pangandaran's rice production. Currently rice production in both villages increased and reach up to 2,154 t per year. Although local government has no accurate data, it is clear that rice in the karst area contributes to the availability of rice in Parigi and Pangandaran.

Farmers in Selasari and Parakanmanggu grow introduced rice recommended by the government, namely Ciherang, IR64 cultivars and currently Inpari 43. However, inhabitant and farmers think that the taste of rice grown in Selasari and Parakanmanggu is better than rice in the market so that they never buy rice. Significant contribution of rice to their daily consumption and income is showed; farmers also sell their surplus rice for additional income. Rice cultivation is local wisdom and very important for food safety; the villages had the silo where the inhabitants store the rice as a reserve when rice cultivation is limited due to water supply shortage.

Rice cultivation patterns in the Parigi karst area carried out by farmers and community is along with the agricultural development model in the karst area proposed by Linhua (1999). The cultivation of economic food crops taken place in moderately deep soil and growing annual crops on the top and ridge of karst hill. However, conservation on karst hills, such as simple terraces and individual terraces has not been done in Parigi except for rice fields (Fig. 3). Terraces in karst areas can reduce erosion, as well as increase water infiltration and soil thickness for plant growth (Linhua, 1999; Urich, 2002).

According to local farmers, ten years ago they can cultivate rice twice or three times a year by irrigating the paddy field with water in the creek and springs even in dry season. Nowadays rice production is really depend on rain water. Due to drought under karst ecological conditions in both village, the yield of rice is low. Although in Indonesia 2.5 million ha of rainfed lowland paddy is the second contributor to rice production after irrigated rice, maintaining the sustainability of rice cultivation under existing karst conditions in both villages is not guaranteed without special efforts. Deforestation and illegal logging by local inhabitants in the karst hill cause serious problem in water availability for paddy field. It is inevitable that now and in the future, planting rice in Selasari and Parakanmanggu needs to lift water from underground waterways.

### **Local Tree Biodiversity**

Karst Hill in both village is believed covered with perennial indigenous trees which used as timber. Intensive logging in the past resulting the devegetation of karst hill. The communities carried out revegetation program by planting sengon tree (*Paraserianthes falcataria* (L.) Niels.) and taro (*Colocasia esculenta* L.) between trees but still leaves open spaces that might induce soil erosion (Fig. 3).

At least 34 local trees grow on karst hill between the rocks and in doline (Table 1). Different indigenous trees grow scattered on karst hills. Tree biodiversity in studied are can be categorized into a group of fruit, wood, herbs, and shade-ornamental trees. The type of tree that can adapt in karst depends on the topography (Guo et al, 2017), soil formation (Atalay, 1991) and the physical and chemical properties of limestone (Efe, 2014).



**Figure 3.** Taro is cultivated by purpose in the ridge of karst hill where the community grows sengan as cash crops

The communities use the trees mainly for food and construction materials, as well as shade plants. The important plants are *Arenga pinnata* (Wurmb) Merrill (Indonesian: Aren; Sundanese: Kawung) and coconut. Starch is extracted from the stem of aren while coconut fruits are purchased; both of commodities are traditional cash crops. Woody plants such as Wangkal, Kiara, Suren, Ki Teja and Ki Rinyuh are utilized as medium quality wood for home construction. Albizia and Kiara (bamboo) are good quality wood that they sell when cash is needed. Bamboo is multipurpose construction material and became a part of the family economy; bamboo is also socially important. The communities used bamboo to build the house, non-permanent buildings and bagan (fishing platform; liftnet) for catching the fish in the ocean; as well as to make stalks for climbing food crops.

Local fruit trees (Kokosan, Nangka and Pisitan) do not provide economic benefits but they are source of vitamins and minerals for the inhabitants. Important economical local legumes trees are Jengkol and Petai since they are a part of local culinary in West Java; while most of the surplus beans was stored, surplus Jengkol and Petai were sold for cash.

Trees are grown in community forest although a part of forest belong to a person or family without certificate of ownership. That natural resources are a social capital correlated to trust, social norms, and social networks developed in the community (Roslinda, Ekyastuti, & Kartikawati, 2017). Local tree in both villages provide a means by which inhabitants can take part in conserve the tree and obtain benefits. The interrelation among forests (trees), agricultural systems and role of people are recognised as key to climate change adaptation. Limited access to tree logging is a way to imply better forest tree preservation to ensure sustainable exploitation of tree products (Matsvange, Sagonda, & Kaundikiza, 2016). In the case of Selasari and Parakanmanggu vilages, ensuring tree growing is a way to sustain the water availability for rice cultivation.

**Table 1.** Indigenous tree grown naturally on the top of karst hill in Batu Lumpang garden, Tawangmangu Village, Parigi District

Local Name	Binomial name	Local Name	Binomial Name
Fruits Tree		Shade and Ornamental Tree	
Kokosan	<i>Lansium domesticum</i> (Corr) cv. Kokosan	Heras/Laban	<i>Vitex pinnata</i> L.
Nangka	<i>Artocarpus heterophyllus</i> Lam.	Huru	<i>Litsea</i> sp.
Pisitan	<i>Lansium parasiticum</i> (Osbeck) Sahni & Bennet	Kanyere	<i>Vitex trofolia</i> L.
Kelapa	<i>Cocos nucifera</i> (L)		
Herbs Tree		Ki Ciyat	<i>Ficus fistulosa</i> L.
Jengkol	<i>Archidendron pauciflorum</i> (Benth.) I.C. Nielsen	Ki Rinyuh	<i>Eupatorium inulifolium</i> Kunth.
Kawung	<i>Arengga pinnata</i> (Wurmb) Merill.	Ki Teja	<i>Daphiniphyllum</i> <i>glaucescens</i> Blume.
Picung	<i>Pangium edule</i> Reinw.	Kiara Tapak	<i>Ficus</i> sp.
Salam	<i>Syzygium polyanthum</i> (Wight) Walp.	Kondang	<i>Ficus variegata</i> Blume.
Wood Tree		Kopeng	<i>Filicium decipiens</i> (Wight & Arn.)
Bambu Awi (Haur)	<i>Phyllostachys</i> sp.	Kopo	<i>Syzygium densiflorum</i> Wall. ex Wight & Arn
Bambu Kiara Suren	<i>Fargesia</i> sp. <i>Toona Sureni</i> (Blume) Merr.	Loa or Ara Mara	<i>Ficus racemosa</i> L. <i>Macaranga tanarius</i> (L.) Müll.Arg.
Shade and Ornamental Tree		Nangsi	<i>Villebrunea rubescens</i> (Bl.)
		Pangsor	<i>Ficus callosa</i> Willd.
		Petai	<i>Parkia speciosa</i> Hassk.
Albasia	<i>Albizia Falcata</i> (L)	Pongporang	<i>Oroxylum indicum</i> (L.) Vent
Bungur	<i>Lagerstroemia speciosa</i> L.		
Cayur	<i>Pterospermum javanicum</i> Jung.	Sulangkar	<i>Leea sambucina</i> (L) Willd
Hantap	<i>Pterocymbium tinctorium</i> Merrill.	Wangkal	<i>Albizia procera</i> (Roxb)
Hampelas	<i>Ficus ampelas</i> Burm. f	Waringin	<i>Ficus benjamina</i> L.

These trees In particular area, rocks have been exposed between the trees showing the removal of vegetation in the past (Fig 4). Vegetation on karst plays an important role in the karst ecosystem because it reduces surface water and guarantees a balance of water infiltrate into the karst system (Liu et al., 2013). Excessive exploitation (logging) of timber tree at certain karst hill has led to deforestation and limited water reserves for rice cultivation.

The sustainability of food crop production in the karst area is not only determined by environmental and cultivation factors, but also depend on regulations and policies of the land use for agriculture in karst landscape. Actually, "Agricultural Area" has been determine by Regional Regulation of Land Use Plan year 2018. The Pangandaran Government has already allocated a total of 20,122 ha of land as the "Sustainable Food Crops Agricultural Zone" in accordance with Law No.41 of 2009 concerning Protection of Sustainable Food Crops Agricultural Land. The purpose of said regulation is

protecting the area and land for food crops agriculture and assuring the availability of sustainable agriculture. Nowadays Pangandaran Regency has not yet Regency Spatial Detail Plan and their zoning regulations. Once the Spatial Detail Plan is put out, the regulation of sustainable agricultural land for food crops should be complied with the plan.



**Figure 4.** Local tree grown naturally in the top of karst hill in Batulumpang Garden where devegetation leaving the bare rocks

Land Use Plan year 2018 also regulates the general provisions on zoning regulations for agriculture in area susceptible to landslide, earthquake, mudslide, or sinking of the earth. Although the regulation does not implicitly mention the karst areas, these general rules remain comply with vulnerable karst areas. Implementation of Karst Landscape Area in Pangandaran will assure the production of rice and other food crops are carried out on the save and legal area. Protected Karst Landscape Area, include their vegetation and hydrology, is important for sustinable food crops production which is in turn enhance communities heath and revenue.

## CONCLUSIONS AND RECCOMENDATION

### Conclusions

Rice cultivation method in both villages are in line with the principles of Integrated Crop Management for lowland rice through the adoption of technology which adjust with local conditions to preserve the nature. Karst area provide land and water for rice cultivation in studied are that contribute to rice production of Parigi District as well as Pangandaran Regency. Although the rice productivity of both villages is lower than average rice productivity of Pangandaran Regency, rice is important to support local inhabitants consumption and family inocme.

A total of 34 local trees include fruit, herbal, wood and shade-ornamental groups were found in the karst of the studied area. Trees benefit the communities by improving air quality, providing shade, increasing family income and providing water for rice cultivation. Lack of irrigation water due to tree logging by inhabitants cause the change in rice planting season. Currently the farmer only grow rice once a year. This situation



threaten the family income, food safety, and sustainable rice production it self. Despite of usefulness of tree in karst area, vegetation conservation and revegetation with local tree has not yet been done.

### Recommendations

This research suggested that local trees need to be studied more as a part of forest or garden conservation which is including establishment local trees nursery to support revegetation with plant adaptive to harsh local conditions. Moreover, the local government should develop permanent irrigation system by taking advantage of underground waterways and spring water. Otherwise the availability of water sources is depend on the tree growing in upper zone of karst area. Sustainable food crop production in the karst area actually has been regulated by some general regulation but land use planning for agriculture in the region should be based on an integrated consideration of rice cultivation and local tree conservation.

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